Special Article

Public-Sector Plant Breeding In a Privatizing World

Public and private plant breeding sectors have developed and coexisted for more than a century in many industrialized countries, but since 1970 the balance between these sectors has shifted. The last third of the 20th century witnessed an acceleration in the type and level of biology applicable to plant breeding, as well as enhanced intellectual property protection for plant varieties. Meanwhile, the forces of globalization and the pressures on public budgets have shifted the balance of plant breeding activity from the public to the private sector.

Throughout the world, a variety of economic forces determine the amount of investment in scientific plant breeding and the relative shares of public and private sector efforts. Private investment in plant breeding is most affected by:

- the cost of research innovation;
- structural market conditions;
- organization of the seed industry;
- the ability of firms to capture the returns to research; and
- the constraint that seed must be sold at a price that will enable the farmer to make a profit.

While public investment in plant breeding is also strongly affected by the cost of innovation, several unique considerations serve to further justify public plant breeding:

- Private firms may not consistently produce a freely available supply of scientific knowledge at a socially optimal level.
- Private and social returns from plant breeding may diverge in cases where firms are unable to profit from the benefits of their research. For example, plant breeding in the past for self-pollinating crops such as wheat was often done by the public sector because private sector firms could not charge enough for seed to make plant breeding profitable. This is largely because farmers could replant seed saved from the previous harvest.
- The desire to earn profits in the near term may lead private firms to operate on a shorter time horizon than would be necessary to attain the broadest basic research objectives.
- Other traits of plant varieties (environmental suitability, including disease resistance and nutritional characteristics) may remain under-researched by private breeding programs.

Today, despite the varying dominance of private plant breeding across crops and countries, mixed linkages between public and private systems are the rule rather than the exception. In the U.S., for example, the public sector maintains the national plant germplasm system, but the private sector does more of the breeding of finished varieties. Traditionally, the private sector relied on public-sector research results. Until the 1970s, for example, public sector inbreds played an important role in U.S. private-sector corn hybrids. Today this is no longer the case. Presently, the public sector may instead utilize private-sector research results in some areas of biotechnology. Funding mechanisms, as well as institutional cooperation and competition in plant breeding, are often quite complex. This has led to considerable discussion of the appropriate roles for public- and private-sector activity.

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Although data on investment in plant breeding are hard to come by—even for the public sector—available information for several industrialized countries shows that, in absolute amounts, the U.S. probably invests more in plant breeding than any other country. In the mid- to late 1990s, annual plant breeding investment for U.S. field crops was an estimated $150-$340 million in the public sector and $260-$410 million in the private sector. These estimates exclude many of the biotechnology investments related to plant breeding. In contrast, Australian public investment in plant breeding for field crops in the early 1990s was valued at just over $30 million. However, if plant breeding investment is divided by the value of output, the U.S. dominance suggested by the absolute totals disappears. For most countries and crops, annual investment in plant breeding is less than 1 percent of the gross value of production—the notable exception is Canadian canola.

In the late 1990s, fueled by huge private and public sector investment in canola breeding, plant breeding investment for major Canadian field crops was valued at over $130 million annually. This canola investment may not be strictly comparable to estimates for other industrialized countries or crops because it includes more expenditures on biotechnology.

In the early 1990s, wheat breeding research expenditures per ton of wheat produced in the United Kingdom were considerably higher than the same estimates for the U.S. On the other hand, wheat breeding investment per ton of wheat is lower in Australia, Germany, and Canada than it is in the U.S.

Public vs. Private: A Case-by-Case Distinction

Crop-specific technical and market factors often determine the relative shares of public and private plant breeding investment. These factors, however, vary over time as well as from country to country.

Real inflation-adjusted investment in public-sector plant breeding in the U.S. rose until the 1980s but began to stagnate during the mid-1990s, followed by a decline. In contrast, from the mid-1960s to the mid-1990s, real private-sector investment in plant breeding grew at a remarkable 7 percent annually. Comprising only one-sixth of the public-sector total in the 1960s, private-sector plant breeding surpassed public investment by the mid-1990s.

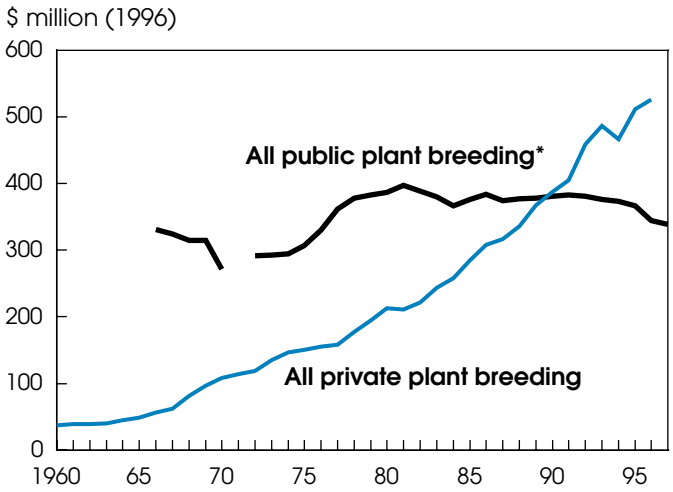
Trends in other industrialized countries are more difficult to trace, but in some European countries, such as France and Germany, private-sector plant breeding has long had a very strong presence. In the United Kingdom, the Plant Breeding Institute at Cambridge, notable for its development of wheat and barley varieties, was privatized in 1987, signaling a general trend. Given the large private-sector investment in canola breeding in Canada, the private-sector total there may now be higher than the public sector's, although public sector breeding is still dominant for the other major prairie crop, wheat. Australian plant breeding still appears to be conducted primarily in the public sector.

Because hybrid crop seed cannot be duplicated, private-sector investors have incentives to favor research that produces hybridized seed. As might be expected, the area of the U.S. planted to field corn is dominated by hybrids developed in the private sector. Private sector hybrids also dominate in the European Union and in Canada. Public-sector inbreds—genestocks which are combined to form hybrids—played an important role in U.S. private-sector hybrids until the 1970s, when their direct influence began a sharp decline.

Public-sector breeding has long prevailed for improving self-pollinating crops, which farmers may replant from seed saved from a previous crop. Yet even in the case of self-pollinating crops, plant breeding has shifted to the private sector over the past 20 years or more. This has happened especially in the U.S. for soybeans and in Canada for canola. Already by 1970, the majority of the U.S. area planted to cotton was planted to private-sector varieties, and today the share has increased to over 90 percent.

Though the private sector's emergence has been abetted by increased intellectual property protection for plant varieties, each crop illustrates the influence of outside factors as well. These include:

Between 1960 and 1997, Private-Sector Outlays for U.S. Plant Breeding Rose More Than Tenfold



1996 dollars are deflated.
*Data for 1971 not available.
Economic Research Service, USDA

- popularity of the corn-soybean rotation, which has led farmers accustomed to buying private-sector corn seed to begin buying private-sector soybean seed as well. The shift from public- to private-sector soybean varieties began at least 20 years ago, well in advance of the introduction of herbicide-tolerant soybeans in the mid-1990s.
- growing impracticability of farmer-saved seed in cotton; and
- payoffs of earlier research in canola sponsored by the edible-oil processing industry, which applied several types of intellectual property mechanisms to protect varieties grown in the field.

Most Australian and Canadian wheat area is still planted to varieties that were developed in the public sector, although a rapidly growing percentage (around 10 percent in Australia and just under 40 percent in Canada) is sown to varieties which are subject to some sort of intellectual property protection. In contrast, European wheat acreage is increasingly dominated by private varieties, reflecting the different breeding histories and stronger plant variety protection of many European countries.

The U.S. situation is intermediate. Over the past 20 years, an increasing proportion of the U.S. wheat area has come to be planted to private varieties. However, private varieties are far more prominent in the soft red winter wheat areas where wheat is grown primarily as a rotation crop, than in the major hard red winter, hard red spring, and white growing areas where public varieties still dominate in farmers' fields. As in the case of soybeans, farmers using purchased seeds for a rotation crop such as corn are more likely to buy private-sector wheat seed.

Special Article

Public-Sector Research Still Finding Its Place

Many prominent plant breeders, as well as a some research policy analysts, are in general agreement about the future role of public plant breeding. In many cases, there is clear economic justification for public-sector investment in activities related to plant breeding. Considerably less consensus exists on determining an appropriate public stance on intellectual property issues. Given the growing role played by the private sector, public research may increasingly respond to voids left by private-sector research, and may be increasingly directed toward the interests of the scientific community at large. Such roles could include the following:

- *Educating and training plant breeders.* By coordinating training efforts between the public and private sectors, the public sector might continue to foster the public goods component of human capital development. To the extent that plant breeding skills are not firm-specific, firms will not invest optimally in training, given the likelihood a scientist might jump to a rival firm. At the same time, private-sector firms require a steady supply of plant breeders with skills that may extend to molecular biology, and even some knowledge of general business theory and intellectual property.
- *Refining and testing methodologies for variety selection.* This would include developing and testing molecular-based systems and developing new methods of selection for desirable traits such as pest resistance. Despite private-sector enthusiasm for some elements of genomics and proteomics (the study of proteins encoded by an organism's genes), scientists still lack a complete understanding of gene action, interaction, promotion, and silencing, which could be used in crop improvement. All life sciences express the need for further advances and more training in computational biology—and knowledge has a public goods component. The public sector does appear to be increasing the proportion of resources directed to more fundamental research.
- *Increasing public commitment to germplasm preservation and development.* Both research analysts and the private sector advocate this role. Germplasm-related activities include collection and preservation of germplasm from crop species and their wild relatives, and incorporation of useful traits from this germplasm into material adapted agronomically to the target region. Social returns are very likely greater than private returns in the germplasm maintenance and pre-breeding areas, unlike the relative returns for variety development. This may be because of differences between social and private discount rates and risk preferences. Furthermore, there are larger barriers to appropriating research returns in germplasm maintenance and pre-breeding than there are in producing finished varieties.
- *Attending to minor crops.* It is somewhat more difficult to argue, with economic reasoning, for public breeding applied to minor crops (i.e., those with small markets). While such specialty crops grow well only in a modest area and are saddled with a limited seed market, their production may still benefit consumers nationwide, and in some cases public breeding may be justified. Since many fruits and vegetables fall under the heading of minor crops, nutritional considerations may direct some public-sector resources to these crops. As it becomes feasible for research on one plant to address plant breeding problems in another plant, at least some of the plant breeding needs of minor crops may be addressed by research on major crops.
- *Solving technological bottlenecks.* The public sector may "invent around" technological bottlenecks due to private ownership of intellectual property. However, public institutions may want to guard against overinvolvement in near-market, product-focused research, at the expense of fundamental research that does not have immediate market applicability. Besides, private firms may also have strong incentives to invent around technological bottlenecks.
- *Identifying problems and limitations of existing agricultural technology, including existing crop varieties.* While the private sector can play a role in the identification of such limitations, the public sector is likely to take a more long-term view, and to represent a broader constituency. For example, the public sector may place more emphasis on the environmental suitability of varieties.

Intellectual Property: Important, But Imperfectly Understood

As plant breeding research moves from conceptual development to later stages, its value may be affected by the intellectual property regime. In the U.S., this regime consists of at least three legal components, as well as the interpretation that has developed around the legislation:

- Plant patents for asexually reproducing species were instituted in 1930.
- Plant varietal protection certificates for sexually reproducing species that are genetically stable—that is, plants that breed true to type—became available with the Plant Variety Protection Act of 1970, which was amended in 1994.
- The U.S. Supreme Court ruled in 1980 that standard utility patents—the major type of patent granted by the Patent and Trademark Office—could be granted to living material, and in 1985 utility patents were explicitly made applicable to plants. Today, utility patents are sometimes granted not only for genetic engineering constructs, but also for entire plants, such as corn inbred lines, corn hybrids, and soybean varieties, even if these plants were developed without the use of "modern" biotechnology. In December, 2001, the Supreme Court upheld the applicability of utility patenting to plants.

Intellectual property regimes affect private-sector efforts both in near-market variety development and investment in more "basic" research such as genomics. More specific recommendations on problems or potential changes in the intellectual property system affecting the life sciences have come more often from lawyers than from economists or, for that matter, from plant breeders.

Economists clearly have a role to play in making theoretical and empirical headway in answering questions about industrial organization and intellectual property, addressing questions such as the following:

- Will the dominant form of private-sector activity in plant breeding come from firms that are considered "life sciences giants" or from those more specialized in agriculture?
- Will large multinational firms supplying new plant varieties be like the pharmaceutical industry, looking for blockbuster products, or like the semiconductor/computer/software industries where a "cumulative innovation" model prevails?

Whatever the answers to these questions, society benefits when the public sector has "freedom to operate"—for example, when it maintains public access to research tools subject to intellectual property protection by the private sector, and when it engages in fruitful collaborative research. In its interaction with the private sector, public-sector plant breeding will benefit from continuous and careful performance review. This review might consider the ways in which public sector research complements, rather than substitutes for, private-sector plant breeding.

Across all the life sciences, precedent determined by internal policy in patent-granting institutions such as the U.S. Patent and Trademark Office, as well as by court decisions, is likely to be at least as important as formal policy revisions by national legislatures. As many of the policy changes in the area of intellectual property will be directed primarily to human health research, agricultural science policymakers are well advised to debate larger science policy issues.

Economists have not reached complete consensus on the economic models of the influence of institutions (such as the intellectual property regime) on both private-sector plant breeding investment and the public sector's freedom to operate and to collaborate with the private sector. Nor have they fully determined the data and methods necessary to test these models. Thus, there is ample room for future economic research to contribute to policy debates over the roles of public- and private-sector plant breeding. Nonetheless, it is clear that public-sector plant breeding will yield the largest social returns if it continues to focus on research directed at carefully identified problem areas, with clear public goods components. AO

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